LIFE HISTORY AND LABORATORY REARING OF *HYDROMETRA HUNGERFORDI* TORRE-BUENO (HETEROPTERA: HYDROMETRIDAE) WITH DESCRIPTIONS OF IMMATURE STAGES[1]

DIANE L. WOOD AND J. E. MCPHERSON

(DLW) Department of Entomology, University of Missouri, Columbia, Missouri 65211; (JEM) Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901.

Abstract.—The life history of *Hydrometra hungerfordi* Torre-Bueno was investigated in southern Illinois during April–November 1992 and 1993, and the immature stages were described. The bug was reared from egg to adult under controlled laboratory conditions. This apparently bivoltine species occurred along the stream banks on the water surface, root mats, and floating detritus. Adults overwintered in leaf litter and became active in April. Eggs were found in May, June, and July above the water level in root mats, tree snags, and associated detritus along the stream bank. Seasonal occurrences of adults and nymphs are discussed. Adults were last observed in early November. This species was reared under a 16L:8D photoperiod and 28 ± 1°C. The incubation period averaged 8.81 days. Durations of the five nymphal stadia averaged 2.52, 2.48, 2.68, 3.39, and 4.68 days, respectively.

Key Words: Water measurer, Hydrometridae, southern Illinois, life history, laboratory rearing, immature stages, descriptions

The family Hydrometridae, which contains about 110 species and seven genera (Smith 1988) in three subfamilies (China and Usinger 1949, Smith 1988), occurs worldwide, although most species are found in the tropics and subtropics (Smith 1988). The largest of the subfamilies, Hydrometrinae, also occurs worldwide and includes the genus *Hydrometra,* the only genus found in America north of Mexico (hereafter referred to as North America). *Hydrometra* is represented in North America by seven to nine species; *H. australis* Say may be conspecific with *H. martini* Kirkaldy, and the supposed occurrence of *H. lillianis* Torre-Bueno, reported only from California, may be in error (Polhemus and Chapman 1979).

Hydrometrids, commonly called marsh treaders or water measurers, are fragile-appearing stiltlike insects with long threadlike legs and antennae, slender bodies, and elongate heads. In North America, they are generally found on or near emergent or floating vegetation associated with still or slowly moving bodies of freshwater, but may move onto open water if disturbed. *H. australis* has occasionally been found in saltwater tide pools in Florida (Herring 1949) and in brackish ponds in Texas (Polhemus and Chapman 1979). Marsh treaders are predaceous, feeding on dead or dying insects

[1] Part of a thesis submitted to Southern Illinois University at Carbondale by the senior author in partial fulfillment of the requirements for the M.S. degree in zoology.

and other microinvertebrates on or within the water film or on floating vegetation (Smith 1988).

Most of the North American species have a limited distribution, the exceptions being *H. martini, H. australis, H. wileyae* Hungerford, and *H. hungerfordi* Torre-Bueno. Not surprisingly, the species with the widest distribution, *H. martini,* is also the species that has been most intensively studied (Polhemus and Chapman 1979).

H. martini occurs from Quebec and Maine south to Florida and west to British Columbia, Oregon, and Arizona (Smith 1988). If *H. australis* is conspecific, then it has also been collected in California, Mexico to Central America, and the West Indies (Smith 1988).

The most thorough studies of *H. martini* are those of Hungerford (1920) and Sprague (1956). Sprague (1956), Polhemus and Chapman (1979), and Bennett and Cook (1981) provide excellent reviews of the earlier literature.

Adults of *H. martini* overwinter in trash surrounding the water, and emerge in early spring (Hungerford 1920). The eggs are about 2 mm long, slender, spindle shaped, sculptured, and stalked. They are laid singly on almost any object above the water surface, and each is affixed at the base of the stalk with a sticky secretion. Eggs are white at oviposition but soon darken.

There are five instars, as in most Heteroptera. Hungerford (1920) stated that the complete life cycle from egg to egg, under the most favorable conditions, was 15 days. Torre-Bueno (1905) and Polhemus and Chapman (1979) stated, respectively, that 25 to 35 days and 21 to 35 days was typical.

Adults generally live seven to nine months under laboratory conditions (Sprague 1956), although Torre-Bueno (1905) reported adults in his laboratory lived up to one year, and one lived 15 months.

H. martini has been reared in the laboratory under unspecified conditions (Martin 1900, Torre-Bueno 1905, Hungerford 1920, Sprague 1956). The egg was first described and illustrated by Martin (1900); it and the instars were subsequently described and illustrated by Hungerford (1920) and Sprague (1956).

H. hungerfordi, as noted above, is also widely distributed. It occurs from Maine south to Florida and west to Kansas and Louisiana (Smith 1988). However little is known about its biology. It has been found in heavily shaded, cool, clear streams with little or no aquatic vegetation (Gonsoulin 1973, Harp 1985) and in slow moving streams, rivers, and swamps (Bobb 1974). Adults have been collected from May through August (Bobb 1974).

This paper presents information on the field life history in southern Illinois and laboratory rearing of *H. hungerfordi* and includes descriptions of the immature stages.

Materials and Methods

Study site.—In summer 1991, a population of *H. hungerfordi* was discovered on Cooper's Creek in Alexander Co., IL. The numbers observed and accessibility of the site suggested a life history study was possible. Therefore, a study was conducted from spring 1992 to fall 1993.

The study site is located in the Mill Creek quadrangle 7.5′ topographic (T145, R1W, N½ of N½ of NW¼ of Sec. 6). Cooper's Creek at this point is classified as a third order stream (Horton 1945). The substrate consists of cobble and gravel with some sand. The width and depth at the center of the channel during spring 1993, when flow was greatest, averaged 6.0 and 0.6 m, respectively. During midsummer, as the water level receded, the stream was reduced to isolated pools. The banks were generally steep sided and undercut, with exposed root mats. Very little emergent vegetation was present. The site was bounded by a riparian zone containing *Acer negundo* L., *Betula nigra* L., *Celtis occidentalis* L., *Juglans nigra* L., *Ostrya virginiana* (Miller), *Prunus serotina* Ehrhart, *Carya cordiformis* (Wangenheim), *Staphylea* sp., *Ranunculus* sp., *Polygonum* sp., *Plantago* sp., *Cirsium* sp., and *Dicentra* sp. Much of this zone was limited to a width of 10–15 m on either side because of agricultural use of the surrounding land.

Life history.—Samples of 10 individuals (adults and/or nymphs) were taken weekly from early spring through early fall. Specimens were hand picked or, for early instars, collected with an aspirator. The few eggs collected (11) were not included in the counts. Adults were identified and released. Immatures were preserved in 75% EtOH and taken to the laboratory for closer examination and to determine the instars. Confirmation of instars was based on comparisons with laboratory reared specimens because published keys were not available for identification. Prey items were also preserved in 75% EtOH.

Laboratory rearing.—Ten pairs of adults were collected from the field and placed in 1 qt Mason jars (1 ♂, 1 ♀/jar). Each jar contained about 200 ml of distilled water and a section of Styrofoam (2 × 1.5 × 1 cm); this floating square provided an additional substrate for walking and served as an oviposition site. The jar was closed with wire screen and secured with the band of the 2-piece mason jar lid. Each pair was fed 5–6 frozen *Drosophila melanogaster* Meigen daily, and the carcasses were removed the following day.

The squares were examined daily for eggs. Eggs were removed and placed in covered petri dishes (about 9 cm diam, 2 cm deep) lined with moistened filter paper on the bottom; distilled water was added as needed to keep the paper moist. Each first instar was placed in a round plastic container (4 cm diam, 5 cm deep). Each container was filled with about 2 cm of distilled water. A wedge of Styrofoam (4 × 3 × 2 cm, 30° angle) was added to serve as an additional substrate for walking. The container was closed with standard fiberglass screening secured with a rubber band. As the immatures developed, molts were recorded and the exuviae removed. First through third instars were fed 2 fruit flies, and fourth through fifth instars 3–4 fruit flies, daily. The containers were kept in incubators maintained at 28 ± 1°C and a photoperiod of 16L:8D (3 florescent "daylight" lamps, about 2800 lux). Distilled water was added to the mason jars and containers as needed to maintain water levels.

Descriptions of immature stages.—The description of each stage is based on 10 individuals. Eggs were selected from those deposited in the laboratory by field collected adults, first through fifth instars from field collected individuals. All had been preserved in 75% EtOH. Drawings were made with the aid of a camera lucida, measurements with an ocular micrometer. Dimensions are expressed in mm as $\bar{x} \pm$ SE (SE < 0.005 listed as 0.00).

Results and Discussion

Life history.—*H. hungerfordi* overwinters as adults. The one adult (female) collected during the winter was found in leaf litter about 2 m from the water edge in early December 1992. Adults emerged in mid-April (Fig. 1A, B); air temperature when they first were observed (11 April 1992), based on data collected at the Anna, Alexander Co., weather station, ranged between 14 and 27°C during the 24 h. They were found continuously during the season near the banks on the detritus and root mats associated with the banks and undercut areas. They and nymphs were never observed in the open channel.

Copulating adults were found throughout the season. Precopulatory behavior was noted on eight occasions; at no time was the male observed to antennate the female. He usually approached her from the side until he was almost in contact and then reoriented until his body was parallel to hers. Upon contact, he would mount her from the side, grasp her with his pro- and mesothoracic legs, extend his genital capsule, and lower the tip of his abdomen to make contact with her genitalia. Pairs were observed in copulo

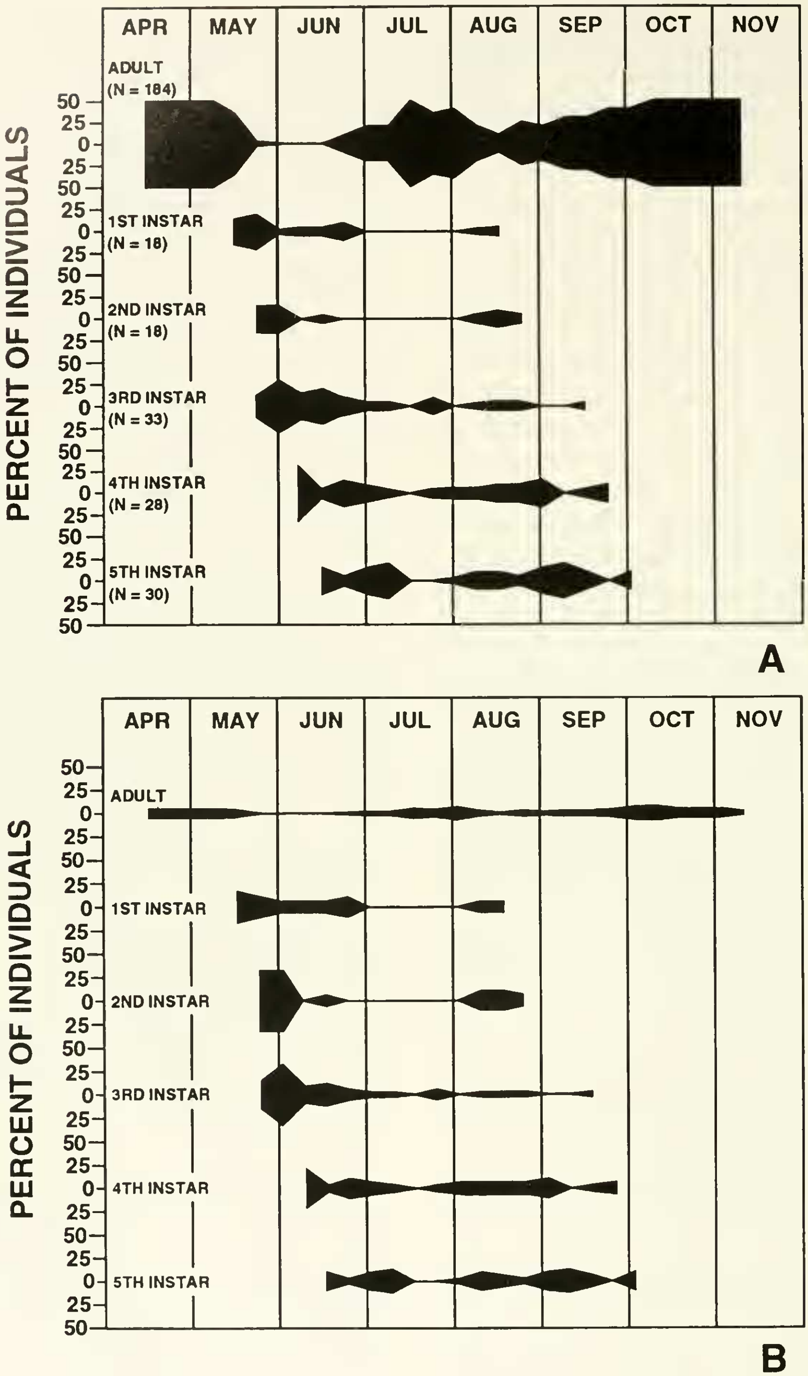

Fig. 1. Field life cycle of *Hydrometra hungerfordi.* A, Percent of individuals of each stage per sample during 1992 season in Alexander Co., IL. B, Percent in each sample of total individuals of same stage collected during the 1992 season in Alexander Co., IL.

up to 5–6 minutes. During this time, females would often move about and feed if prey were located. On one occasion, a copulating male was physically dislodged by another male. The second male then attempted, repeatedly, to mount the female. She prevented his attempts by dislodging him with her legs and finally left the area.

Eggs were found in early May (4), late June (2) and mid-July (5). They were laid on root mats, tree snags, and associated detritus. Generally, they were laid 6–10 cm above the water surface in dark, moist areas and always affixed to the substrate by the base of the egg.

First instars were found from mid-May to mid-August, second instars from late May to late August, third instars from late May to mid-September, fourth instars from early June to late September, and fifth instars from mid-June to early October (Fig. 1A, B).

First and second instars were often found in the back reaches of the undercut bank. If they were disturbed when in more exposed areas, they would invariably flee beneath the bank. Third, fourth, and fifth instars were generally found in the more open areas, but never far from the bank.

H. hungerfordi, as evidenced by the peaks in abundance of the adults and nymphs, is apparently bivoltine in southern Illinois (Fig. 1A, B).

Several prey items were noted during this study (Table 1). The hydrometrids were observed to actively capture small prey (i.e., collembolans), but only noted feeding on larger prey.

H. hungerfordi adults and nymphs were occasionally observed attempting to feed on nymphs. In one instance, an adult was noted antennating a third or fourth instar. It then extended its beak and attempted to probe the nymph, which then fled.

As *H. hungerfordi* walked across the surface film and floating detritus, it moved its antennae from side to side. When it encountered potential prey, it positioned its antennae over the specimen. If the specimen was acceptable, the beak was extended and used to probe and then pierce the prey. If the prey was small, the hydrometrid lifted the now impaled prey and, generally, carried it near or onto the stream bank.

Table 1. Feeding records of *Hydrometra hungerfordi* from a stream in Alexander Co., IL, in 1992 and 1993.

Taxon	No. of specimens
Collembola	
Isotomidae	
Isotomurus palustroides Folsom[a]	2
Entomobryidae	
Entomobrya socia Denis[a]	1
Tomocerus flavescens Tullberg[a]	1
Ephemeroptera	
Leptophlebiidae	
Paraleptophlebia sp.[a]	1
Coleoptera	
Dytiscidae	
Hydaticus sp.[b]	1
Diptera	
Culicidae	
Anopheles crucians Wiedemann[a]	1
Chironomidae	
Polypedilum sp.[b]	1
Cyprinodontiformes	
Fundulidae	
Fundulus sp.[c]	1

[a] Adult.
[b] Larva.
[c] Egg.

The use of the antennae to locate prey has also been reported in other hydrometrid species by Andersen (1982). He noted an invagination at the apex of the fourth antennal segment bordered by modified hairs and suggested this area may have an olfactory function.

An encounter between an adult *H. hungerfordi* female and a lycosid spider was observed on one occasion. The spider grabbed and pulled the female towards its mouth and then immediately flung it away. The female was observed for about 10 minutes and appeared unharmed by the encounter.

Sprague (1956) felt there probably was little or no predation on adult *H. martini* because of the hard exoskeleton, fusion of

Table 2. Duration (in days) of each immature stage of *Hydrometra hungerfordi* under controlled laboratory conditions.

Stage	Number completing stadium	Range	$\bar{x}$ ± SE	Cumulative mean age
Egg[a]	181	8–10	8.81 ± 0.05	8.81
Nymph				
1st instar	178	1–4	2.52 ± 0.05	11.33
2nd instar	178	1–6	2.48 ± 0.05	13.81
3rd instar	143	2–4	2.68 ± 0.06	16.49
4th instar	103	2–5	3.39 ± 0.08	20.88
5th instar	41	3–7	4.68 ± 0.13	25.56

[a] 200 eggs were laid.

body parts, and lack of thin intersegmental membranes.

H. hungerfordi usually flees when disturbed. If it is unable to do so, it often will drop to the surfaces of the detritus and root mats with the prothoracic legs and antennae directed anteriorly and the meso- and metathoracic legs directed posteriorly, all appendages in line with the body, and remain motionless. This behavior was noted on seven occasions. During these times, the animal was difficult to see.

Laboratory rearing.—Eggs were laid 2–3 cm above the water surface on the walls of the mason jars and on the upper surface of the Styrofoam. They were laid singly with the base of the stalk attached to the surface. The female would touch the tip of her abdomen to the surface and then slowly move away as she extruded the egg.

The egg was white when first laid, but darkened to light brown within eight hrs. Eye spots were visible within five days. The egg burster was visible one to two days later. The incubation period averaged 8.81 days (Table 2).

The first instar emerged through a longitudinal slit along one side at the cephalic end of the egg. Emerging nymphs were transparent except for their red eyes. They were observed feeding within three to four hours.

The first through fifth stadia averaged 2.52, 2.48, 2.68, 3.39, and 4.68 days, respectively (Table 2). The total developmental period averaged 25.56 days. Highest mortality ocurred during the fifth stadium and resulted primarily from incomplete ecdysis.

Descriptions of immature stages.—*Egg* (Fig. 2A–D): Length, 1.90 ± 0.02; width, 0.28 ± 0.01. Egg fusiform; comprised of distal micropylar projection, central region, and basal pedicel. Eggs laid singly, glued at base of pedicel to living or dead plant material; white at oviposition, becoming gold to brown during maturation. Chorion of micropylar projection and of most of pedicel with scalelike sculptering; each scale apparently with several pores. Apex of micropylar projection with single micropyle. Central region with alternating ridges and furrows.

Nymphal instars: The first instar is described in detail, but only major changes from previous instars are described for subsequent instars. Length is measured from tip of head to tip of abdomen, width across pronotum. Additional measurments are given in Table 3.

First instar (Fig. 3A): Length, 1.70 ± 0.07; width, 0.24 ± 0.01. Body slender, elongate, greatest width at prothorax; general ground color of head and thorax light brown dorsally and laterally, yellowish to white ventrally; ground color of abdomen usually yellowish to white on all surfaces; ecdysial line evident dorsomedially, yellowish white, arising at posterior margin of head, bifurcating near anterior margin of eyes; body sparsely setose dorsally and laterally,

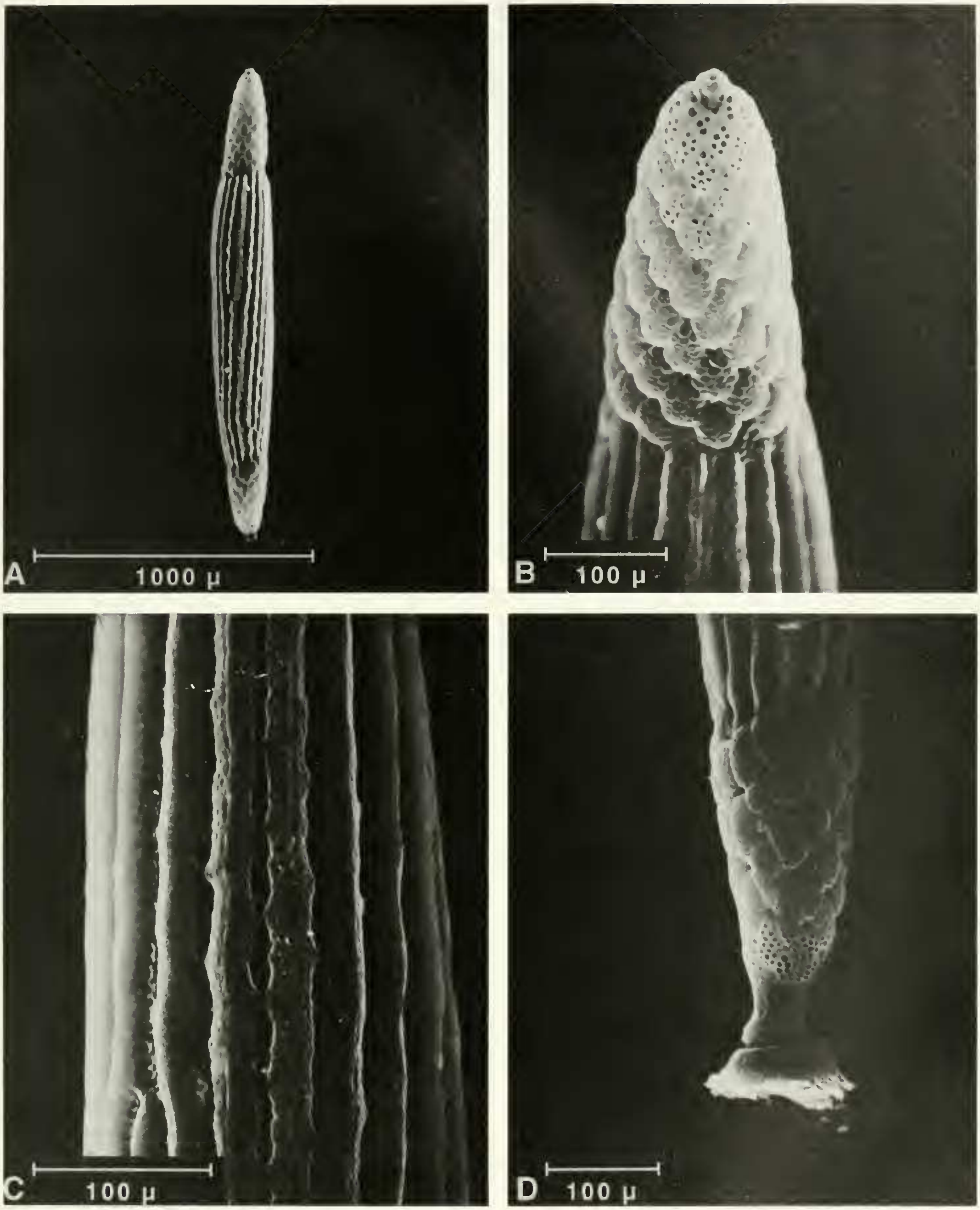

Fig. 2. Scanning electron micrographs of egg of *Hydrometra hungerfordi.* A, Egg. B, Micropylar region. C, Central region, D, Basal region.

more heavily setose ventrally except on head posteroventral to eyes where setae are absent.

Head scelerotized, elongate, narrow; anteocular area subrectangular, constricted just anterior to eyes, area about 1.4× length of postocular area; postocular area narrowing anteriorly. Anteclypeus rectangular, sub-

Table 3. Measurements (mm)[a] of *Hydrometra hungerfordi* instars[b].

	Nymph				
	1st instar	2nd instar	3rd instar	4th instar	5th instar
Body length[c]	1.70 ± 0.07	2.31 ± 0.10	3.54 ± 0.13	5.46 ± 0.15	7.97 ± 0.10
Head length[c]	0.61 ± 0.01	0.85 ± 0.02	1.11 ± 0.01	1.67 ± 0.03	2.45 ± 0.03
Anteocular	0.28 ± 0.01	0.43 ± 0.01	0.63 ± 0.01	0.95 ± 0.02	1.47 ± 0.02
Postocular	0.20 ± 0.00	0.28 ± 0.01	0.44 ± 0.02	0.54 ± 0.01	0.76 ± 0.01
Width across eyes	0.23 ± 0.00	0.25 ± 0.01	0.30 ± 0.01	0.35 ± 0.01	0.43 ± 0.01
Synthlipsis	0.09 ± 0.00	0.09 ± 0.00	0.10 ± 0.00	0.11 ± 0.01	0.12 ± 0.01
Antennal segs.					
1st	0.14 ± 0.00	0.18 ± 0.00	0.22 ± 0.00	0.30 ± 0.00	0.38 ± 0.01
2nd	0.19 ± 0.00	0.29 ± 0.01	0.39 ± 0.01	0.56 ± 0.01	0.80 ± 0.01
3rd	0.73 ± 0.02	1.06 ± 0.01	1.45 ± 0.02	1.88 ± 0.02	2.42 ± 0.00
4th	0.86 ± 0.01	0.99 ± 0.01	1.13 ± 0.01	1.26 ± 0.01	1.41 ± 0.01
Notal lengths[c]					
Pronotum	0.17 ± 0.01	0.20 ± 0.01	0.28 ± 0.00	0.44 ± 0.00	0.74 ± 0.01
Mesonotum	0.14 ± 0.01	0.21 ± 0.01	0.30 ± 0.01	0.40 ± 0.01	0.42 ± 0.01
Metanotum	0.07 ± 0.00	0.09 ± 0.00	0.10 ± 0.01	0.23 ± 0.01	0.52 ± 0.01
Width at pronotum	0.24 ± 0.01	0.26 ± 0.01	0.28 ± 0.01	0.34 ± 0.01	0.40 ± 0.01
Abd. length	0.71 ± 0.06	0.96 ± 0.10	1.75 ± 0.12	2.72 ± 0.12	3.84 ± 0.09
Leg lengths					
Profemur	0.56 ± 0.01	0.79 ± 0.01	1.09 ± 0.01	1.48 ± 0.03	2.16 ± 0.03
Protibia	0.74 ± 0.01	1.04 ± 0.01	1.43 ± 0.02	1.93 ± 0.02	2.74 ± 0.02
Protarsus	0.27 ± 0.00	0.30 ± 0.01	0.36 ± 0.01	0.44 ± 0.01	0.59 ± 0.01
Mesofemur	0.58 ± 0.01	0.85 ± 0.01	1.18 ± 0.01	1.66 ± 0.03	2.45 ± 0.02
Mesotibia	0.78 ± 0.01	1.12 ± 0.01	1.56 ± 0.01	2.12 ± 0.03	3.02 ± 0.02
Mesotarsus	0.27 ± 0.00	0.31 ± 0.00	0.39 ± 0.01	0.48 ± 0.01	0.64 ± 0.01
Metafemur	0.78 ± 0.01	1.15 ± 0.02	1.49 ± 0.12	2.19 ± 0.04	3.14 ± 0.03
Metatibia	1.08 ± 0.02	1.60 ± 0.03	2.23 ± 0.02	3.07 ± 0.05	4.33 ± 0.03
Metatarsus	0.27 ± 0.00	0.31 ± 0.01	0.38 ± 0.01	0.47 ± 0.01	0.62 ± 0.01

[a] $\bar{x}$ ± SE.
[b] Based on 10 individuals per instar.
[c] Measured at midline.

truncate apically, extending beyond bases of antennae. Area ventrolateral of anteclypeus and anterior to antennal sockets not readily divisible into maxillary plate and ventral lobe. Labrum narrow, transverse, located just anterior to anteclypeus. Beak 4-segmented; segments 1 and 2 short, narrow, subequal in length; segment 3 longest of segments, about 6.0× length of segment 1 and 2 combined; segment 4 about 0.4× length of segment 3. Eyes red, granular, located laterally about midway along length of head. Three pairs of trichobothria; first pair at base of anteclypeus close to midline, second pair dorsolateral and posterior to antennal bases; third pair dorsolateral, near posterior margin of head; each trichobothrium arising from tubercle. Antennae 4-segmented, filiform, segment 4 slightly fusiform distally; segment 1 shortest; ratio of antennal segment lengths about 1:1.3:5.1:6.

Thoracic nota scelerotized; middorsal, longitudinal ecdysial line continuous with that of head. Pronotum quadrangular; anterior margin overlapping posterior margin of head; posterior margin straight laterally, convex medially. Mesonotum at midline about 0.8× length of pronotum; subquadrangular; posterior margin slightly convex. Metanotum at midline about 0.5× length of mesonotum; rectangular; posterior margin slightly concave. Thoracic pleura visa-

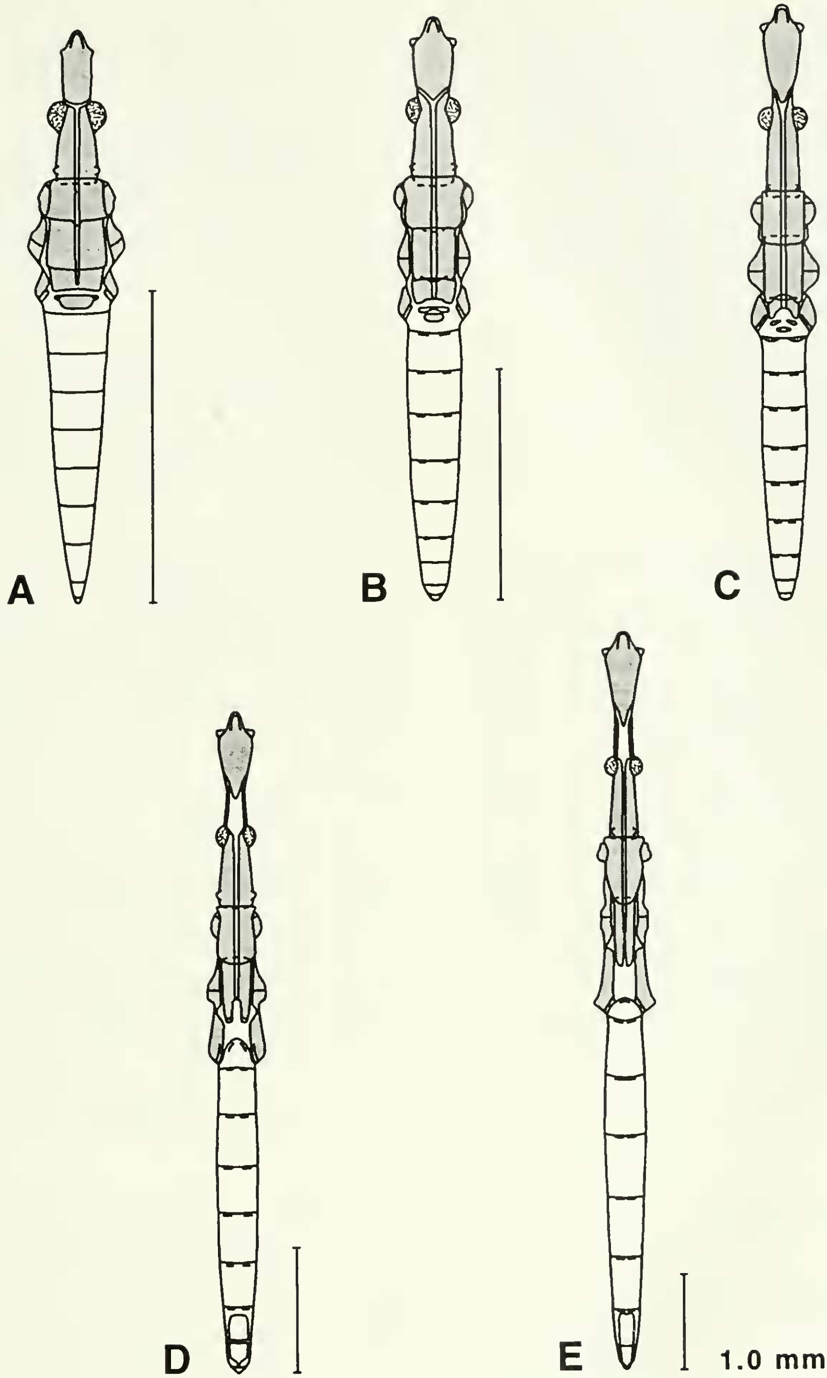

Fig. 3. Nymphal stages of *Hydrometra hungerfordi*. A, First instar. B, Second instar. C, Third instar. D, Fourth instar. E, Fifth instar.

ble in dorsal view, particularly those of meso- and metathoraces; each pleuron divided by suture into episternum and epimeron. Thoracic sterna lightly sclerotized; sclerotization best developed on prosternum; prosternum narrowest of thoracic sterna. Thoracic spiracles present; spiracle 1 present on proepisternum adjacent to intersegmental line; spiracle 2 present on mesoepisternum near intersegmental line.

Legs light brown; coxae subconical; trochanters cylindrical; femora, tibiae, and tarsi slender, elongate, each increasing in length on pro-, meso-, and metathoraces, respectively; tarsi 1-segmented, each terminating in two claws.

Abdomen yellowish to white, occasionally with red, red often present as dorsolateral stripes; tergum 1 with subtrapezoidal tergal plate; terga 2–6 membranous; terga 7–10 with dorsal surface sclerotized, sclerotization on terga 9–10 occasionally extending to and including ventral surface. Sternum 1 intimately associated with metasternum; sterna 1 and 2 not readily distinguishable from each other; sterna 3–8 membranous; sterna 9–10 membranous or sclerotized. Spiracles present on segments 1–8; those on segment 1 located dorsolaterally, those on segments 2–8 ventrolaterally.

Second instar (Fig. 2B): Length, 2.31 ± 0.10; width, 0.26 ± 0.01. Anteocular area widest at antennal bases, narrowest just anterior to eyes; about 1.5× length of postocular area; postocular area narrowest at posterior margin of eyes, widening to base of head; area ventrolateral of anteclypeus partially divided into maxillary plate and ventral lobe; maxillary plate adjacent to anteclypeus, dorsal to ventral lobe. Ratio of antennal lengths about 1:1.6:5.9:5.5.

Pronotum with posterior margin subtruncate, overlapping anterior margin of mesonotum. Mesonotum at midline about 1.1× length of pronotum; rectangular; posterior margin subtruncate, overlapping anterior margin of metanotum. Metanotum at midline about 0.4× length of mesonotum; rectangular, posterior margin more concave; wing pads evident at posterolateral corners.

Abdominal tergum 1 with 2 sclerotized plates; anterior plate narrow, transverse, constricted medially; posterior plate transverse, elliptical. Terga 2–7 with paired small, transverse, linear plates adjacent to intersegmental lines.

Third instar (Fig. 3C): Length, 3.54 ± 0.13; width, 0.28 ± 0.01. Anteocular area about 1.4× length of postocular area. Area ventrolateral to anteclypeus divided into maxillary plate and ventral lobe. Area posteroventral to eyes with few, scattered setae. Ratio of antennal segment lengths about 1:1.8:6.5:5.1.

Pronotum narrower, rectangular. Mesonotum at midline about 1.1× length of pronotum; rectangular; posterior margin concave; wing pads well developed, slightly overlapping metanotum. Metanotum at midline about 0.3× length of mesonotum; posterior margin strongly concave; wing pads well developed.

Abdominal tergum 1 with 3 sclerotized plates; first 2 as anterior pair, small, oblique; third plate posterior, transverse, elliptical.

Fourth instar (Fig. 3D): Length, 5.46 ± 0.15; width, 0.34 ± 0.01. Ecdysial line still linear posterior to eyes, broader between and anterior to eyes to basal ¼ of anteocular length before bifurcating. Setae more numerous posteroventral to eyes. Anteocular area about 1.8× the length of postocular area. Ratio of antennal segment lengths about 1:1.9:6.3:4.2.

Pronotum with posterior margin rounded, slightly overlapping mesonotum. Mesonotum at midline about 0.9× length of pronotum; wing pads well developed, extending over and usually covering metanotal wing pads. Metanotum at midline about 0.6× length of mesonotum; sclerotized or membranous; wing pads often hidden by mesonotal wing pads, occasionally exposed apically.

Abdominal tergum 1 with 3 sclerotized

plates; first two as anterior pair, small, oblique; third plate posterior, weakly developed or absent. Abdominal terga 1–6 with continuous, white, mediolongitudinal stripe bordered on either side by red stripe. Tergum 7 with rectangular, sclerotized plate. Tergum 8 with medial projection on posterior margin of sclerotized plate; projection generally larger in females. Sternum 8 occasionally with small, medial plate of variable shape.

Fifth instar (Fig. 3E): Length, 7.97 ± 0.10; width, 0.40 ± 0.01. Body more setose. Anteocular area about 1.9× length of postocular area. Ventral lobe more developed, reaching beak segment 1. Ratio of antennal segment lengths about 1:2.1:6.4:3.7.

Pronotum with posterior ⅓ narrowing posteriorly, rounded apically. Mesonotum at midline about 0.6× length of pronotum; wing pads covering metanotal wing pads. Metanotum at midline about 1.2× length of mesonotum; membranous other than wing pads.

Tergum 8, in males, with dorsomedial projection that does not exceed tip of abdomen. Tergum 9 narrow, collarlike, extending and widening laterally where it reaches abdominal sternum 9. Sternum 7 with pair of longitudinal, rectangular plates. Sternum 8 with quadrangular plate, no split present. Sternum 9 large, cuplike. Sternum 10 either lost or associated with formation of ventral side of proctiger.

Tergum 8, in females, with dorsomedial projection that extends to or beyond abdominal tip. Sternum 7 with pair of longitudinal, rectangular plates. Sternum 8 with quadrangular plate that reaches lateral margin; plate with mediolongitudinal split; split varying from complete to limited to distal ½, widening posteriorly. Sternum 9 with pair of small quadrangular plates; plates continuing laterally and dorsally as sclerotized ring. Sternum 10 either lost or associated with formation of ventral side of proctiger.

Diagnosis.—The five nymphal instars, in addition to size, can be readily separated by the relative proportion of the anteocular and postocular areas; presence or absence, and degree of development, of wing pads; and length of metafemora. There is a progressive increase of the anteocular area relative to the postocular area through all the instars. Wing pad development becomes apparent in the second instar with progressive development in the subsequent instars: mesonotal wing pads begin to overlap the metanotum in the fourth instar and completely cover the metanotal wing pads by the fifth instar. Finally, all leg segments progressively increase in length through the instars, but increase is most readily seen in the metafemur.

Acknowledgments

We thank the following faculty and staff members of Southern Illinois University at Carbondale: J. A. Beatty and W. G. Dyer, Department of Zoology, for their critical reviews of the manuscript; and the entire staff of the Research Photography and Illustration Facility, for their technical expertise and preparation of the final drafts of the figures. We also thank R. J. Snider, Department of Zoology, Michigan State University, Lansing; B. M. Burr and J. B. Stahl, Department of Zoology, SIUC; and D. W. Webb, Illinois Natural History Survey, Champaign, for identification of prey items; and R. W. Sites and Becky J. Nichols, Department of Entomology, University of Missouri, Columbia, for the SEM photographs of the eggs.

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